Scintillation measurements at Bahir Dar during the high solar activity phase of solar cycle 24

Norbert Jakowski[1], Martin Kriegel[1], Hiroatsu Sato[1], Jens Berdermann[1], Volker Wilken[1], Stefan Gewies[1], Nikolai Hlubek[2], Mogese Wassaie[3], and Baylie Damtie[3]

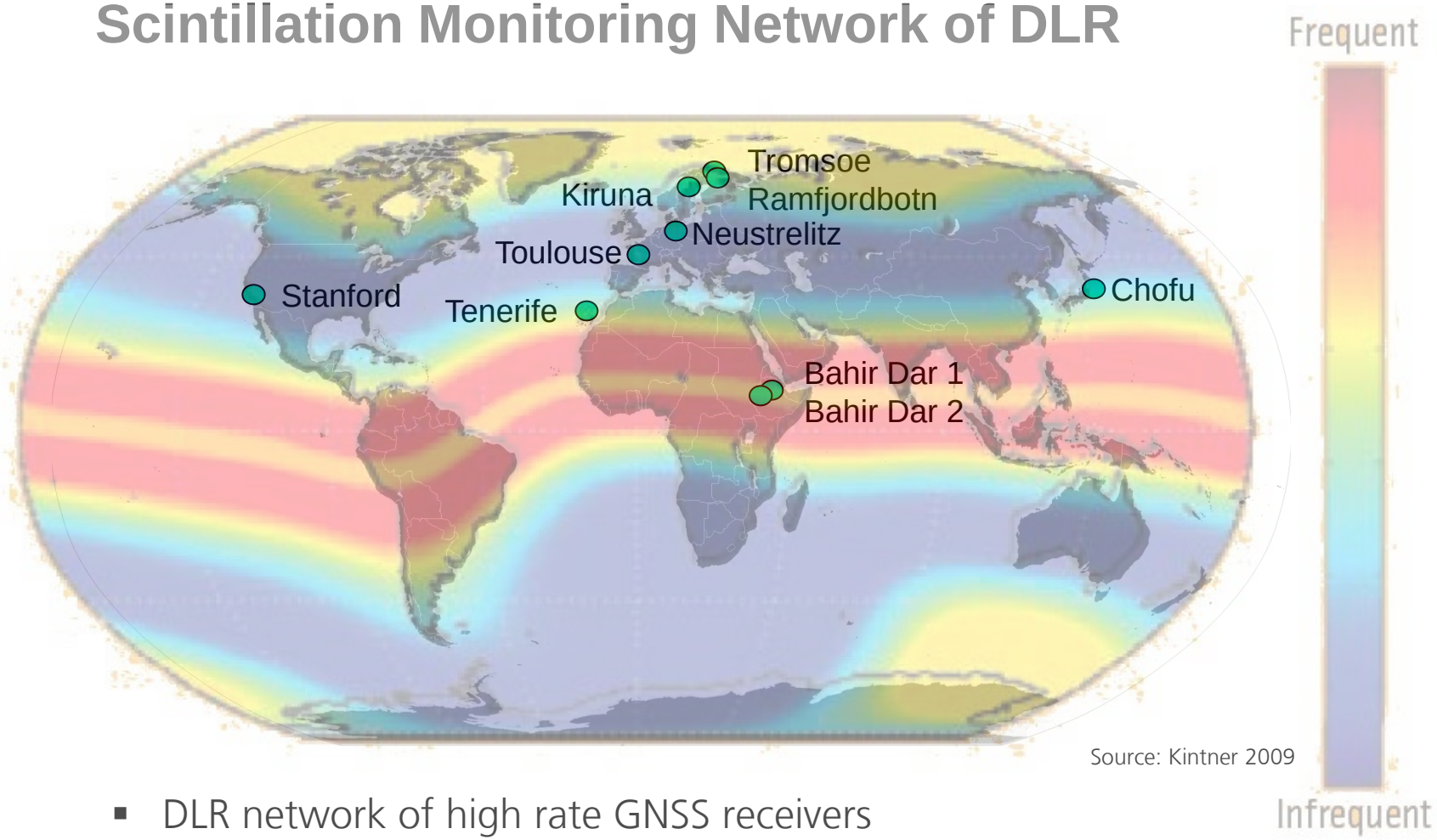
[1] Institute of Communications and Navigation, German Aerospace Center, Neustrelitz, Germany
[2] gateprotect GmbH, Leipzig, Germany
[3] Washera Geospace and Radar Science Laboratory, Bahir Dar University, Ethiopia

DLR

Outline

- Introduction
- Data base and monitoring techniques
- Data analysis
- Observations
- Preliminary two-station case study
- Summary & Conclusions

Scintillation Monitoring Network of DLR

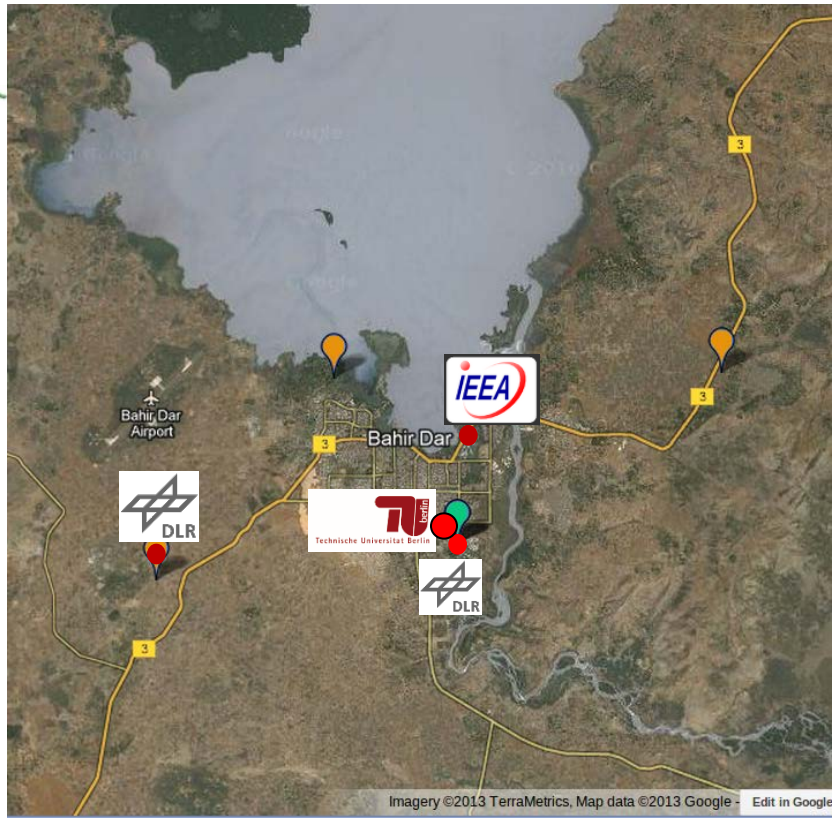


Source: Kintner 2009

- DLR network of high rate GNSS receivers
- Network provides scintillation data distributed via IMPC/SWACI http://swaciweb.dlr.de

Current scintillation receiver network in Bahir Dar

Javad receiver, 50 Hz sampling rate



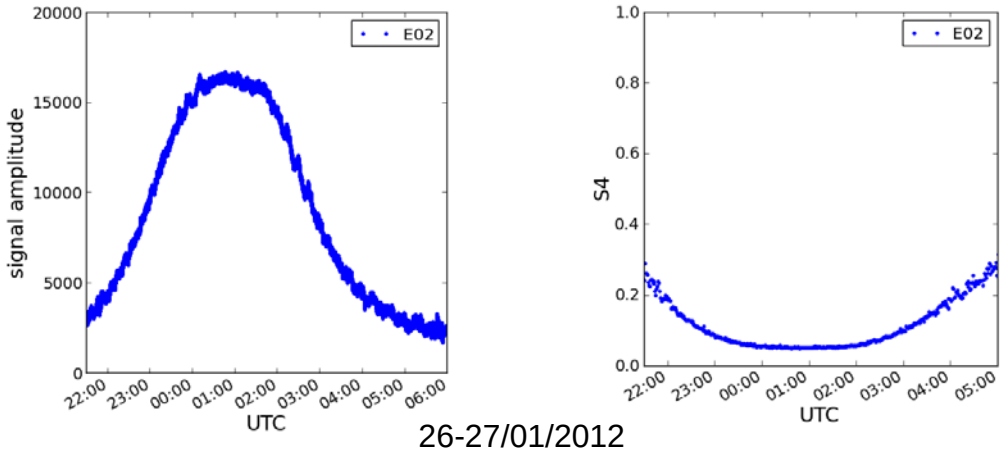
DLR 1

Sites with receiver

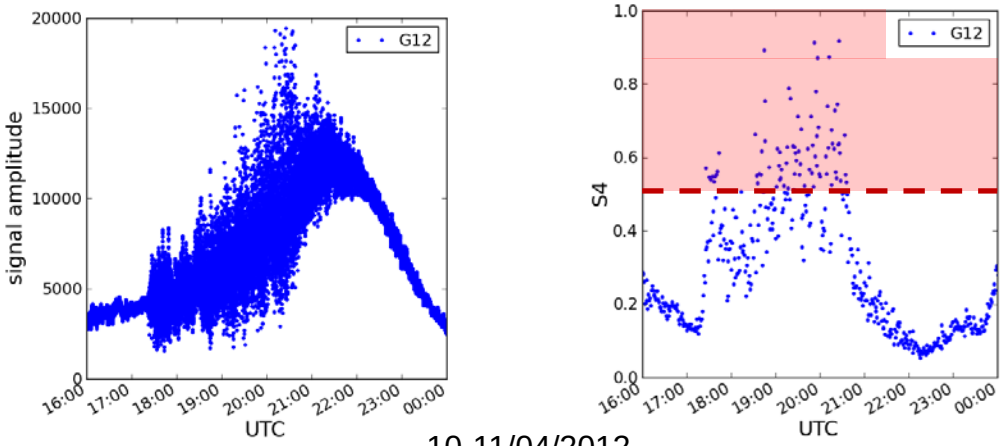
Installation of DLR GNSS 2 in June 2014

DLR

Amplitude scintillations



26-27/01/2012



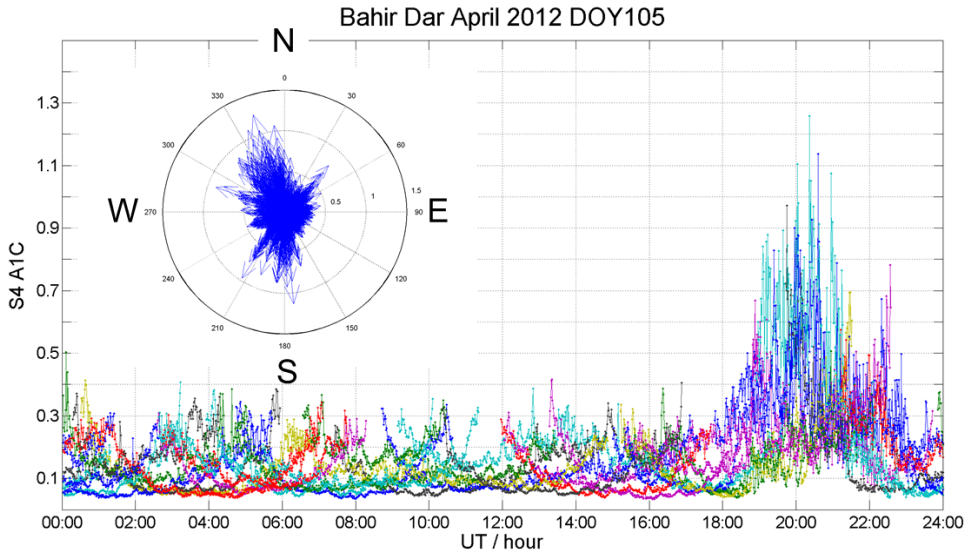
10-11/04/2012

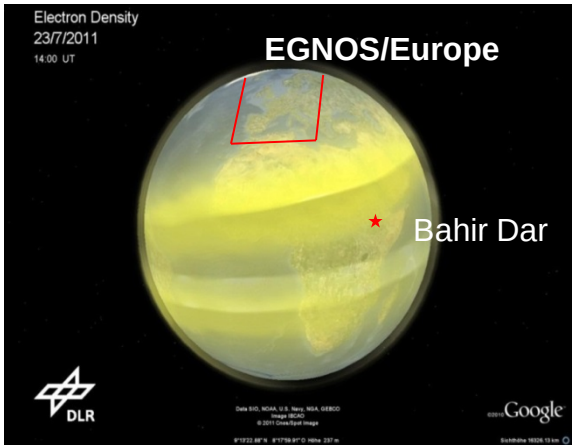
$$S_4 = \left(\frac{\langle SI^2 \rangle - \langle SI \rangle^2}{\langle SI \rangle^2} \right)^{1/2}$$

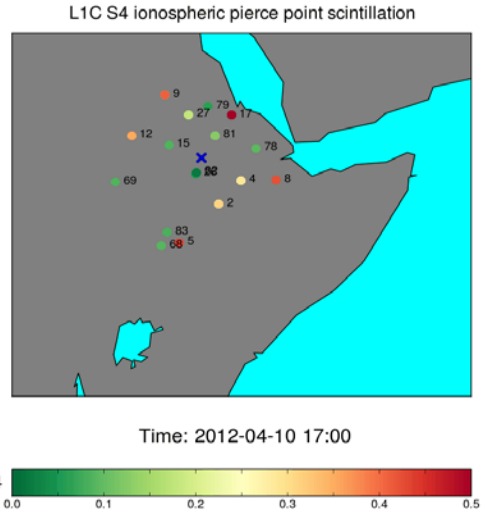
Enhancement of S_4 at low elevation due to multipath effects. Effect has to be mitigated in subsequent analysis.

S_4	
< 0.3	low noise
0.3 to 0.5	enhanced
> 0.5	scintillation event

Diurnal variation of scintillation activity at Bahir Dar



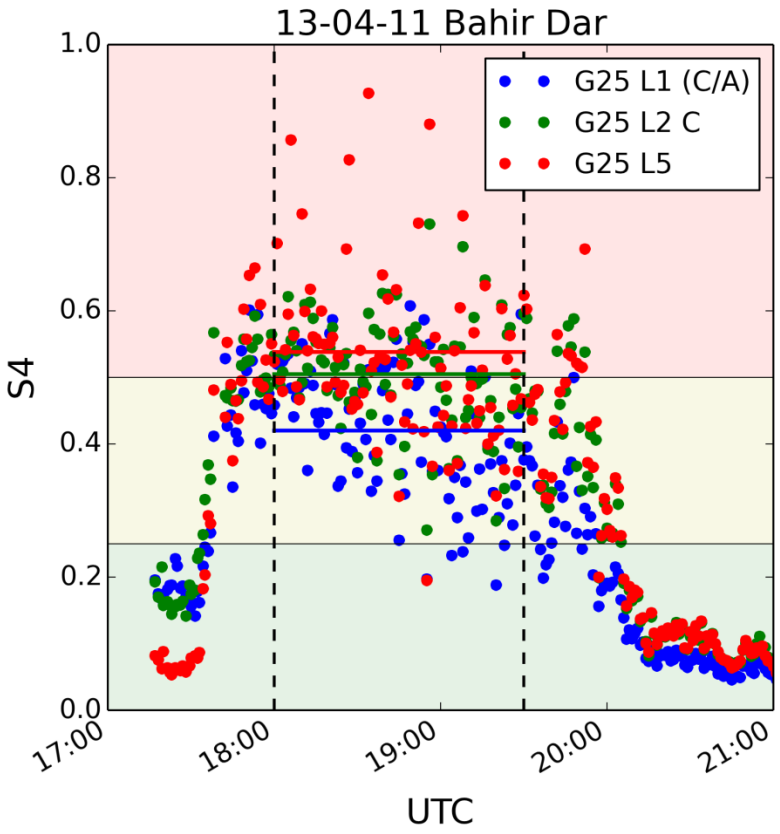




S_4 Scintillation activity enhances regularly in Bahir Dar / Ethiopia after sunset

Scintillations occur primarily in North-South direction

Different GNSS signals - one day one satellite



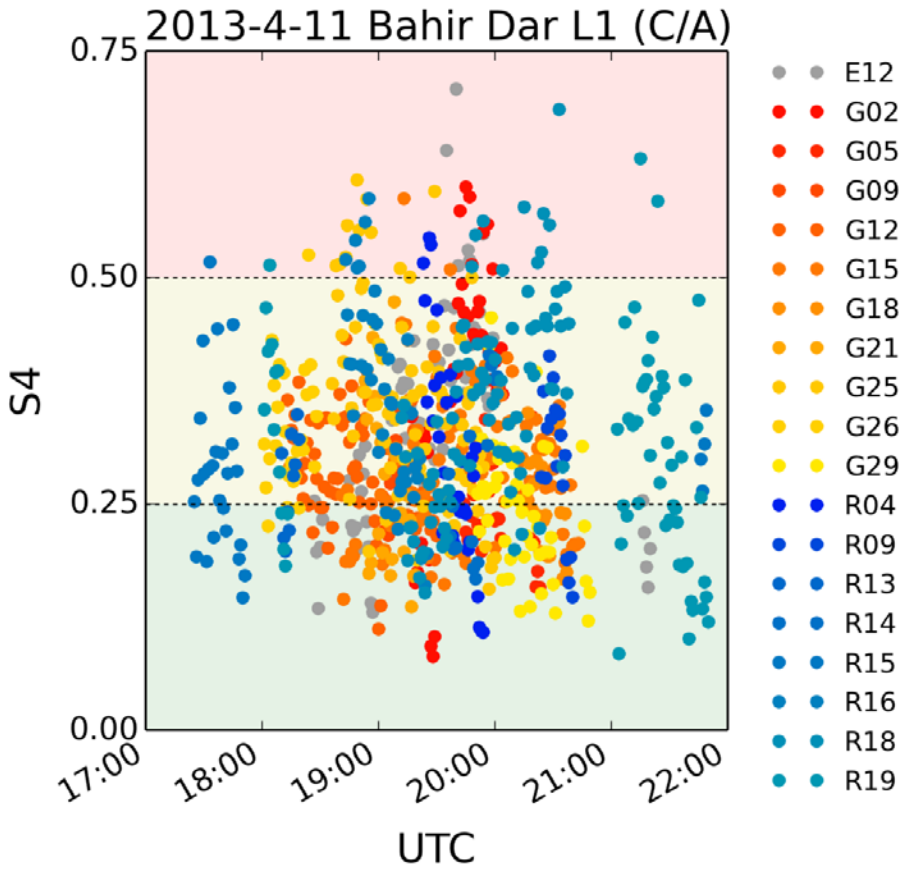
Signal	Mean	Std. dev.
L1 (C/A)	0.42	0.098
L1 p(y)	0.64	0.11
L2 p(y)	0.63	0.11
L2 C	0.50	0.084
L5	0.54	0.183

Precise p-code could not be encrypted, reconstuction technology degrades SNR.

Encrypted signals are ignored in subsequent analysis.

[Hlubek et al. , SWSC, 4, A22, 2014]

Preprocessing of scintillation events



Problem:

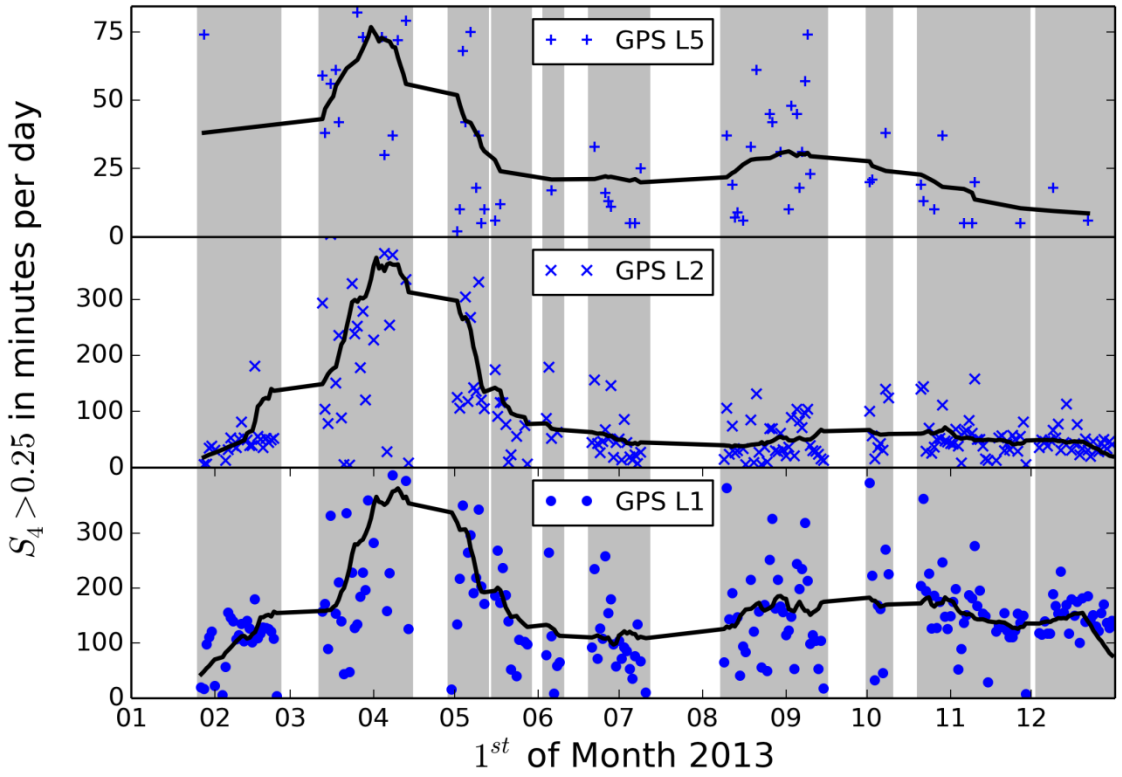
Only few large events with S_4> 0.5, not sufficient for statistical analysis

Solution:

Elimination of weak scintillation events whose origin is unknown with soft barrier around S_4=0.25

[Hlubek et al. , SWSC, 4, A22, 2014]

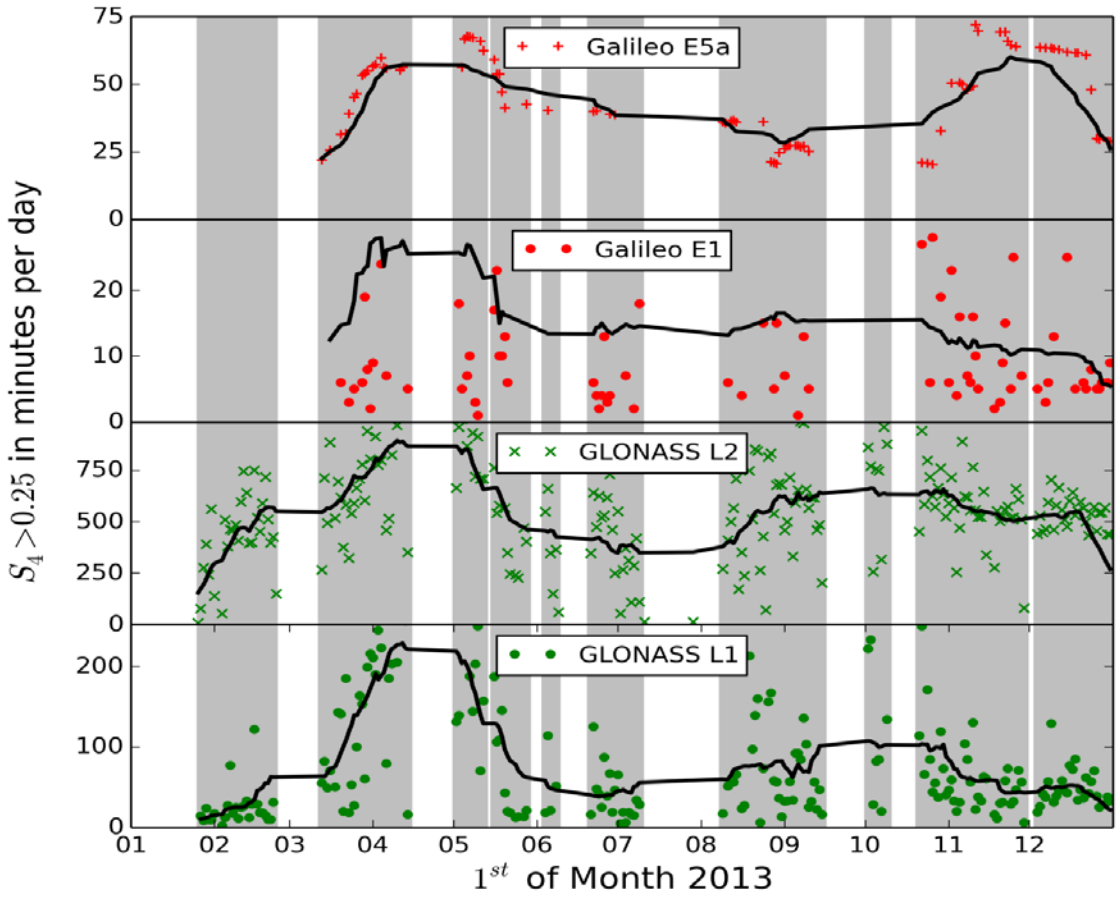
Seasonal variation of scintillation occurrence - GPS



Occurrence peaks at equinoxes

Significant difference between spring and autumn equinoxes, probably due to different levels of solar activity:
Spring : <Rz>= 57.1
Autumn: <Rz>=44.0

Seasonal variation of scintillation occurrence – GLONASS, Galileo

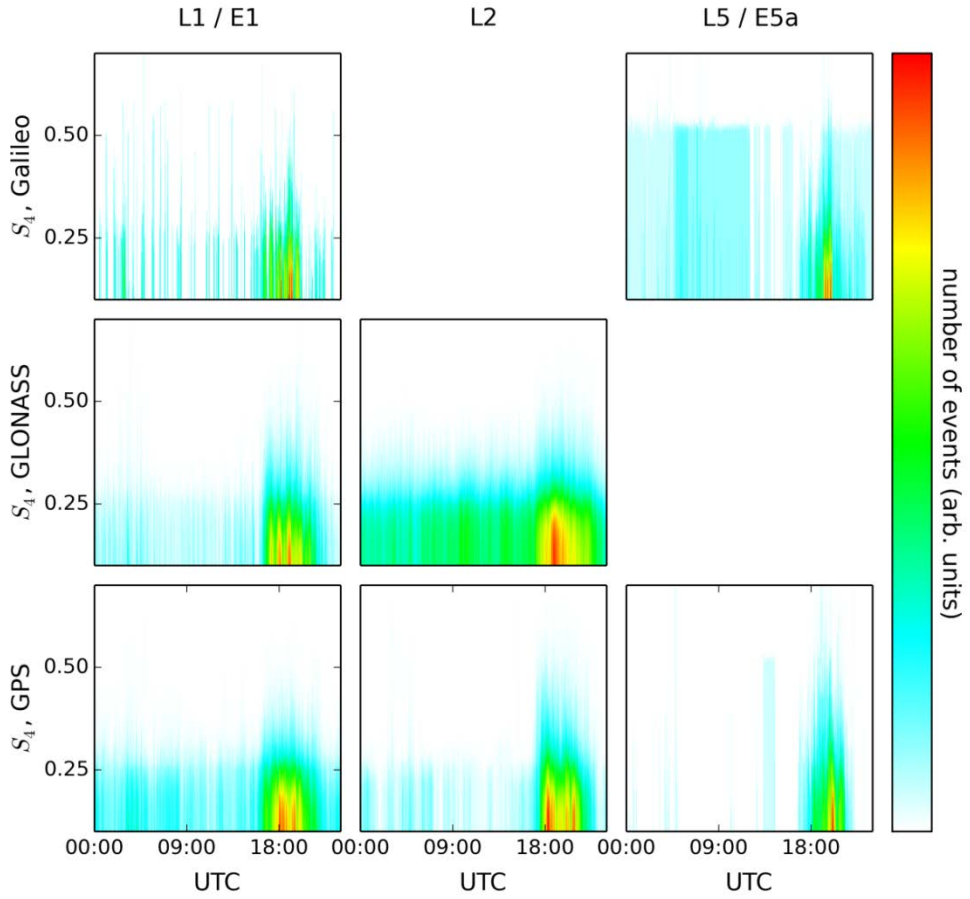


Occurrence peaks at equinoxes

Significant difference between spring and autumn equinoxes, probably due to different levels of solar activity:
Spring : <Rz>= 57.1
Autumn: <Rz>=44.0

All GNSS show similar behavior at mostly all frequencies.

Diurnal variation of scintillation occurrence

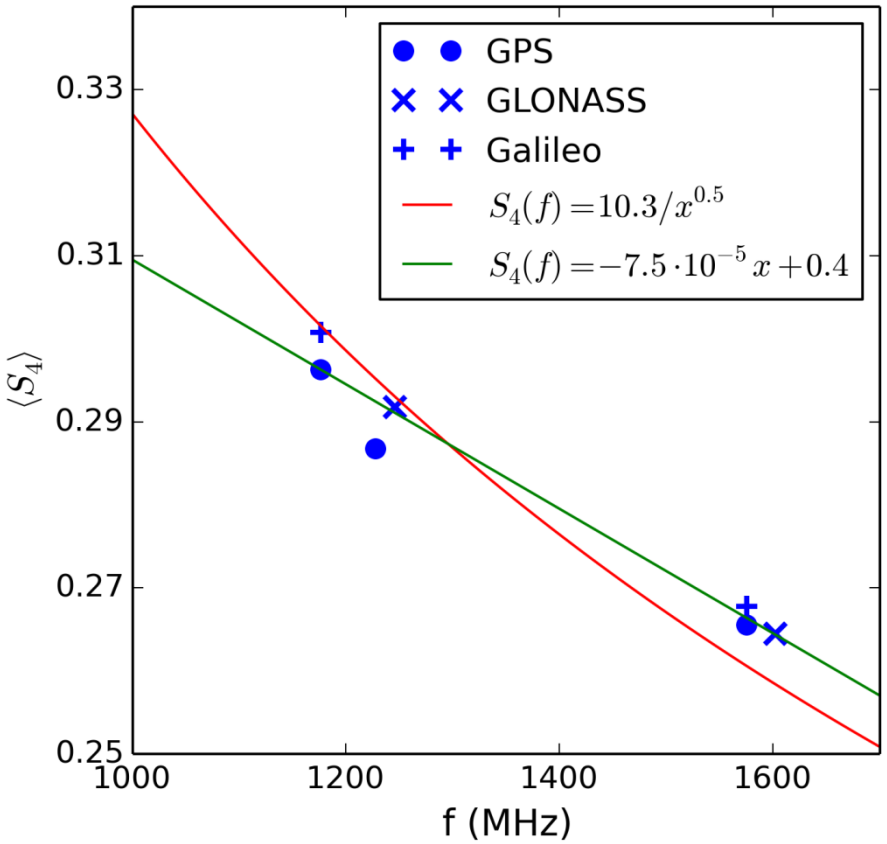


Number of satellites :
GPS: 32
GLONASS: 23
Galileo: 4

Due to the quite different data base, statistics provides only some preliminary results.

Galileo, GLONASS(L2) strongly affected

Scintillation strength as function of frequency



Observed frequency dependence covers only a small frequency range.

Ogawa et al. (1980) found for 136 ≤ f ≤ 1700 MHz:

$S_4 \sim 1 / f^{0.5}$

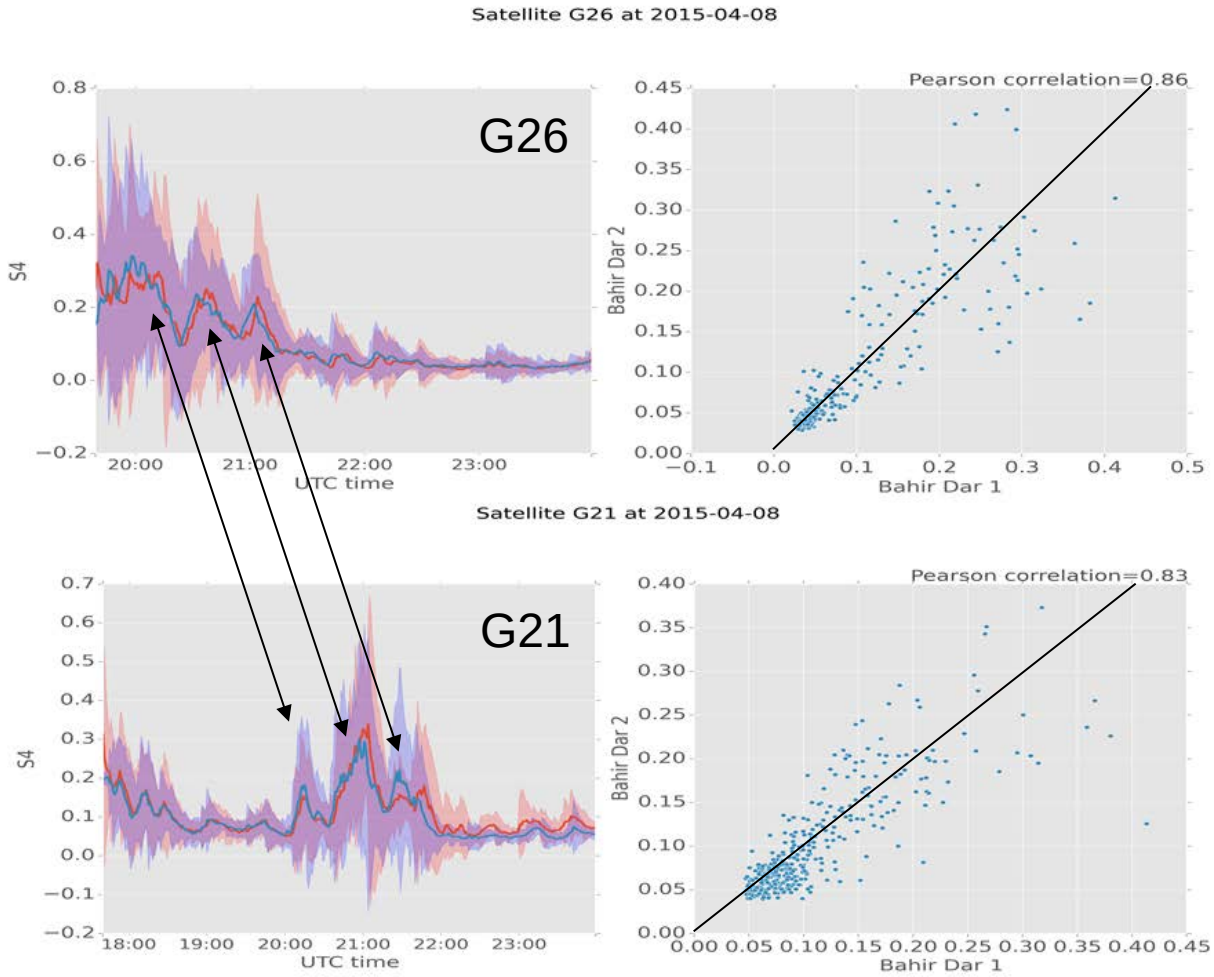
agrees with L1-L2-L5 tendency

[Ogawa et al. , JATP, 42(7),1980]

Outline

- Introduction
- Data base and monitoring techniques
- Data analysis
- Observations
- Preliminary two-station case study
- Summary & Conclusions

S_4 correlation of both DLR stations on 8 April 2015



Distance: 7.16 km

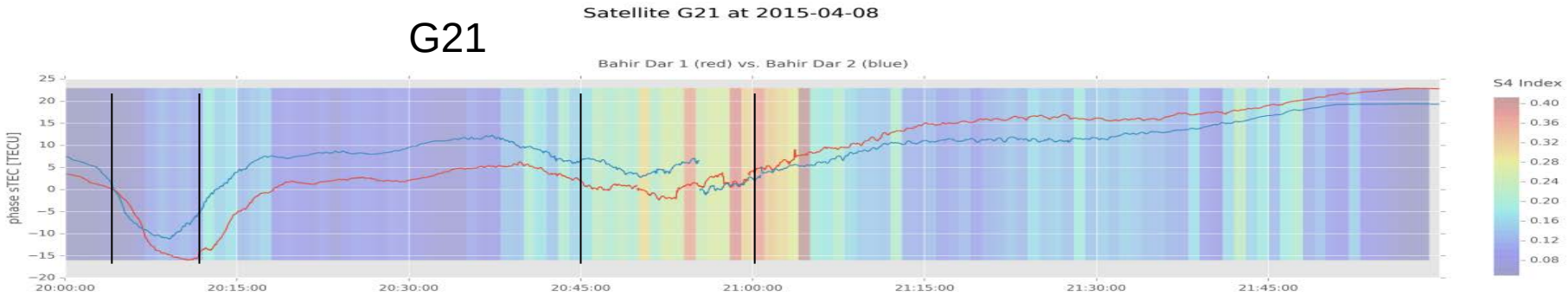
Direction:
≈ East (I) – West (II)

Left panel
Mean S_4 index
Background: ±4 σ
Station I: red
Station II: blue

Right panel
Cross correlation of
S_4 from both stations

TEC depletions on 8 April 2015

G21



TEC depletion I

$\Delta STEC_{-} \approx 18$ TECU

$T_{Dep} \approx 7.5$ min

$S_{4max} \approx 0.2$

TEC depletion II

$\Delta STEC_{-} \approx 9$ TECU

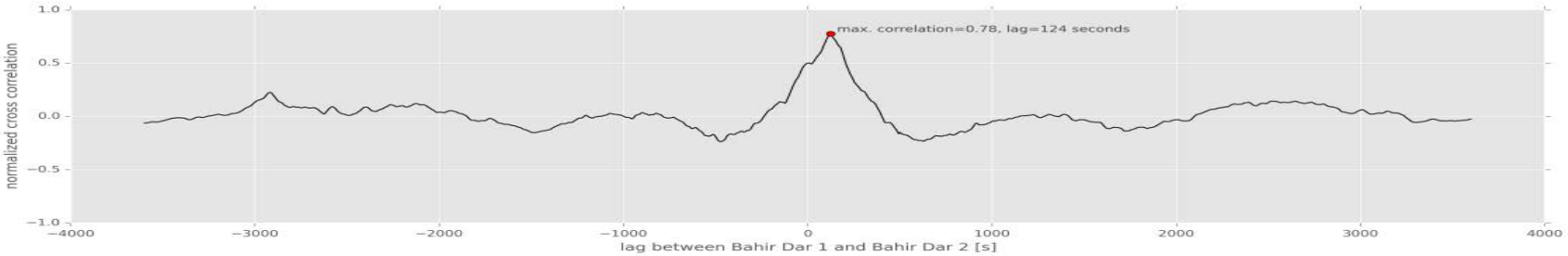
$T_{Dep} \approx 15$ min

$S_{4max} \approx 0.4$

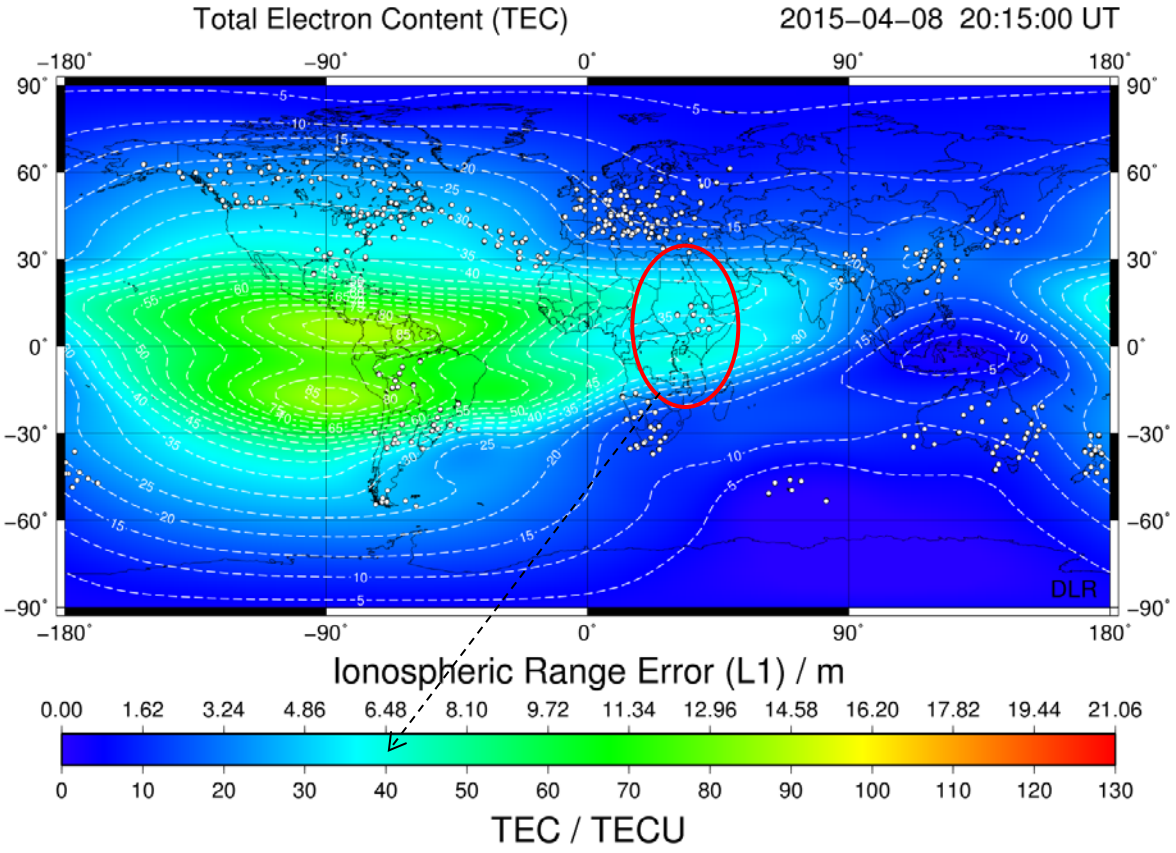
East-west distance between stations: 7.16 km

Time delay: 124 s

Max(cc): 0.78



Background ionization provided by TEC



Global TEC mapping in near real time is based on 1 s GNSS data from geodetic networks (ASI, IGS, EUREF) provided in streaming mode via NTRIP technology.

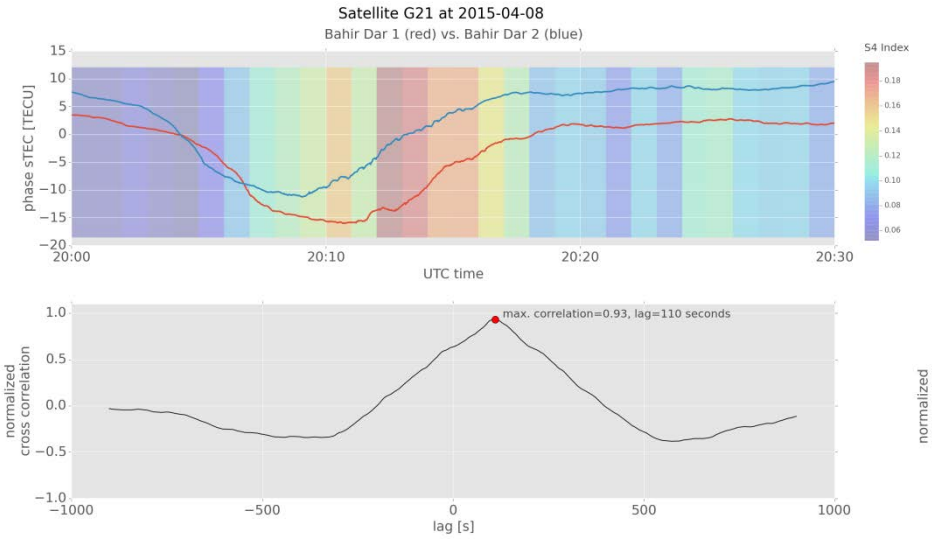
Actual data products incl. movies available via DLR IMPC service.

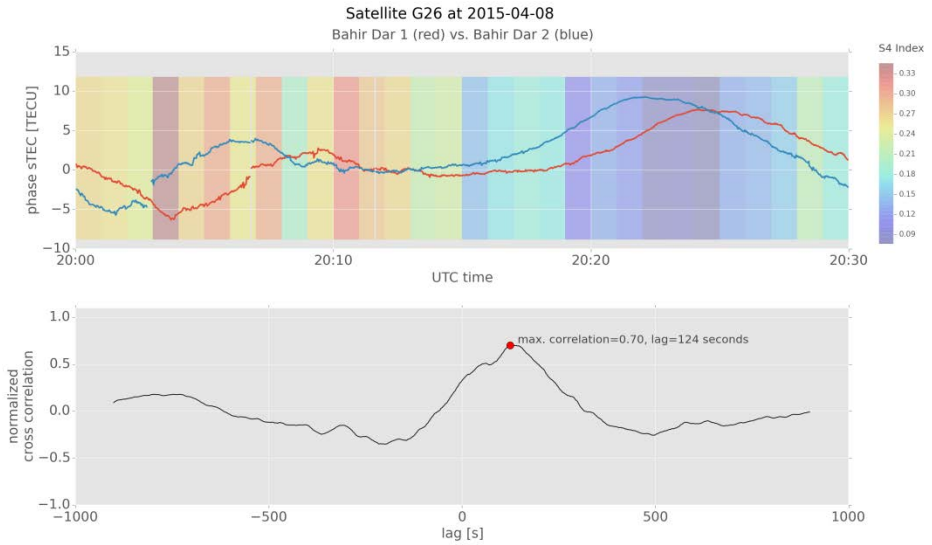
http://swaciweb.dlr.de

$\Delta TEC_{-}(I,II) \approx 20 - 30\%$

Background model: Jakowski et al, J. Geod., 85(12), 965–974, 2011
Mapping technique: Jakowski et al., Radio Sci., 46, RS0D18, 2011

TEC depletion around 20:10 UT at G21/26





TEC depletion 1/G21

Max(cc): 0.93

lag: 110 s

$v_O \approx 65$ m/s ($v_D \approx 80$ m/s)

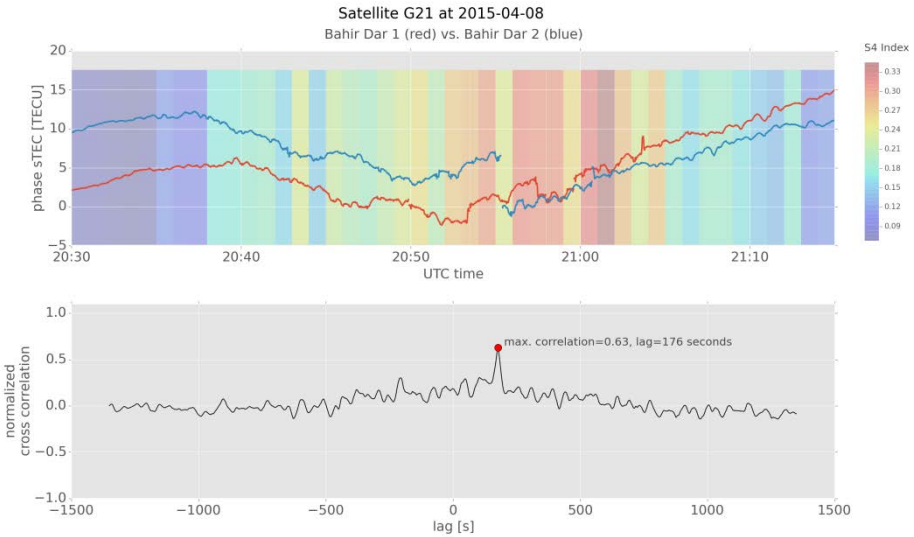
TEC depletion 1/G26

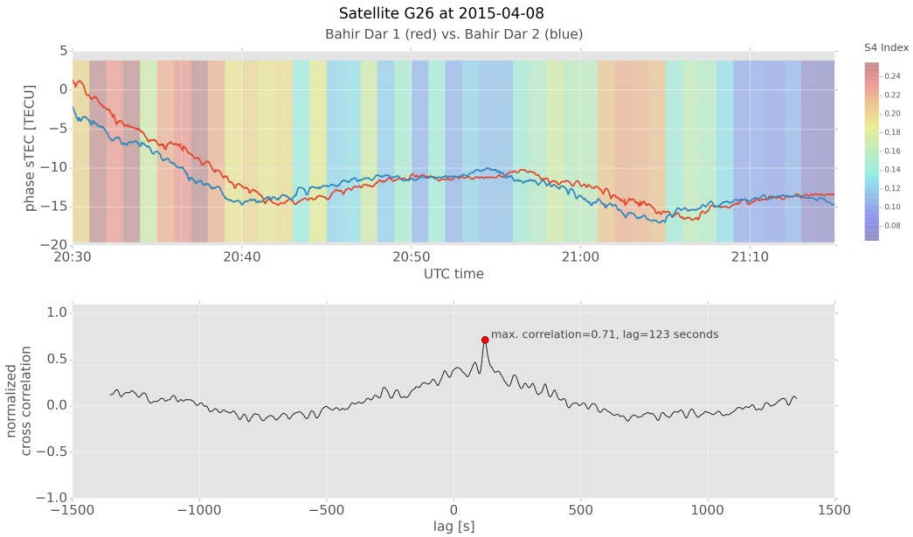
Max(cc): 0.70

lag: 124 s

$v_O \approx 58$ m/s ($v_D \approx 84$ m/s)

TEC depletion around 20:50 UT at G21/26





TEC depletion 2/G21

Max(cc): 0.63

lag: 176 s

$v_O \approx 41$ m/s ($v_D \approx ?$ m/s)

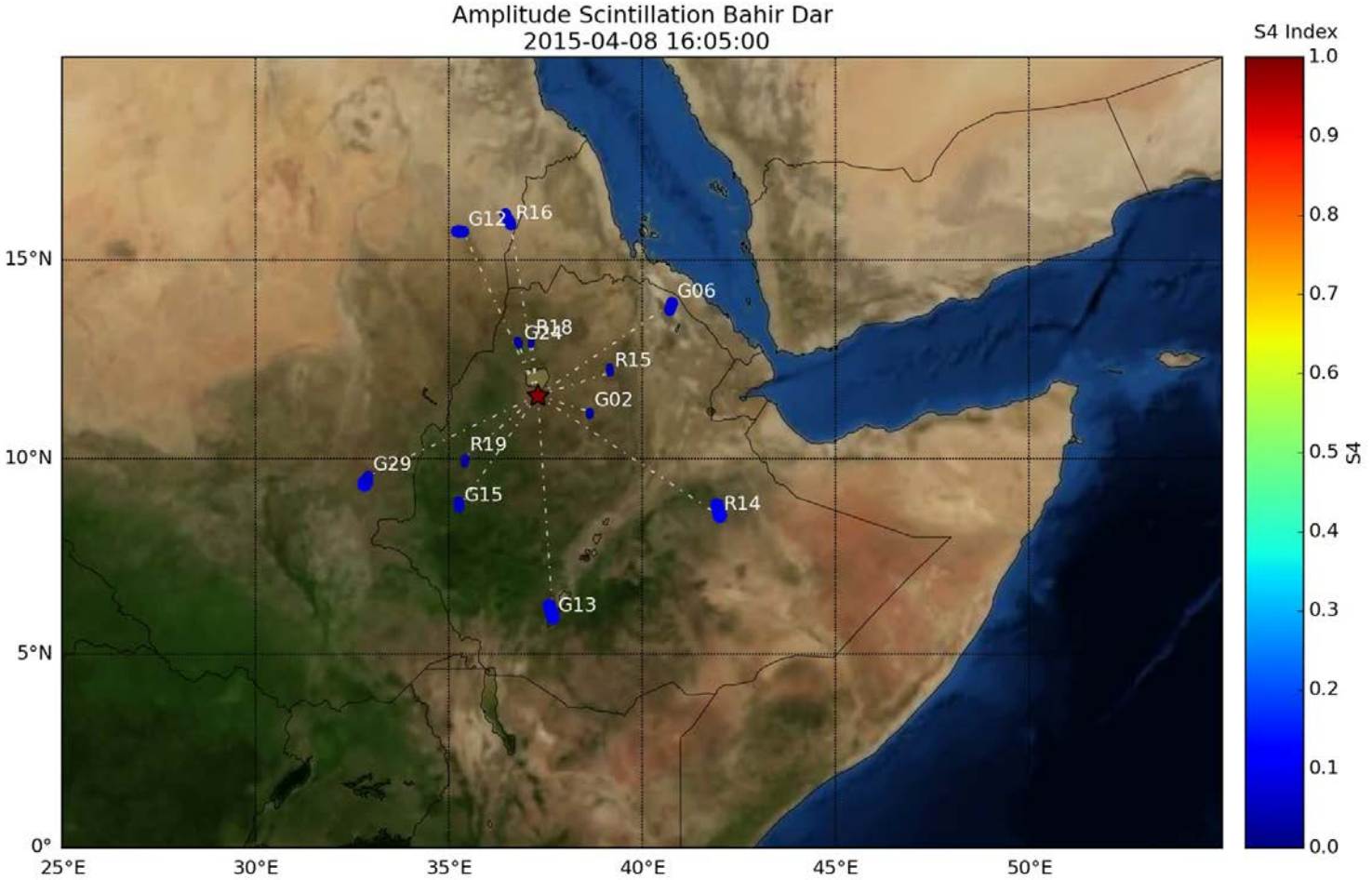
TEC depletion 2/G26

Max(cc): 0.71

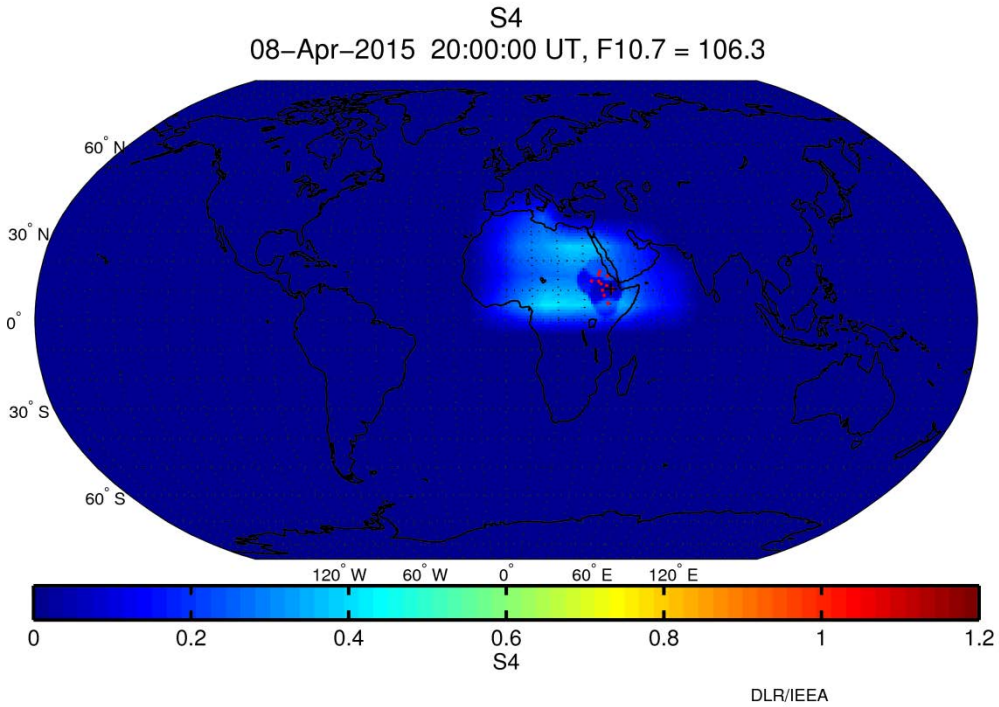
lag: 123 s

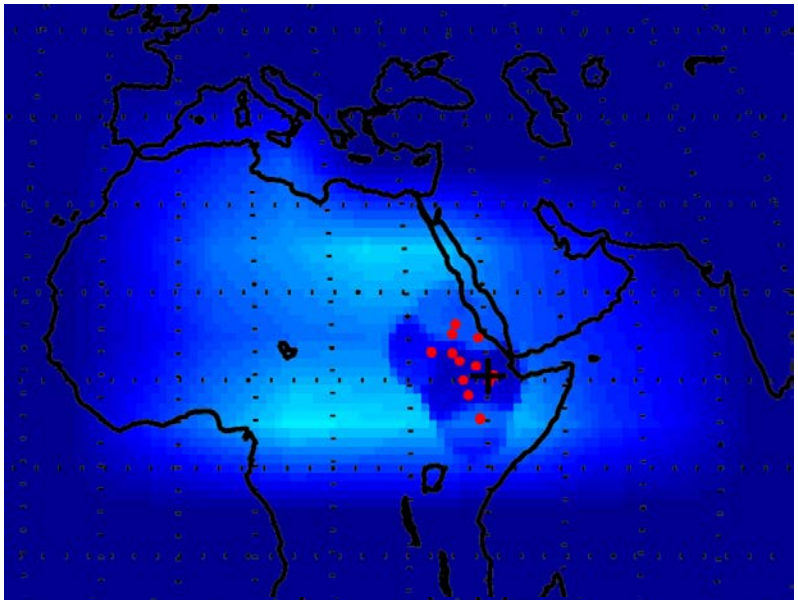
$v_O \approx 58$ m/s ($v_D \approx 78$ m/s)

Scintillation activity along different satellite links



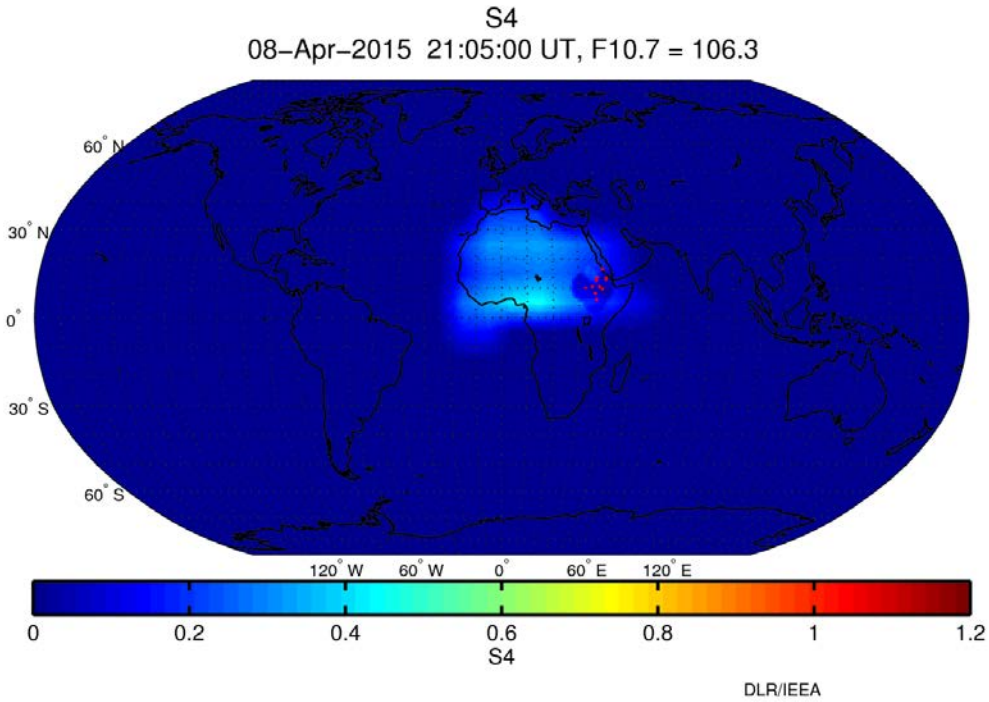
Scintillation map on 8 April, 2015, 20:00 UT

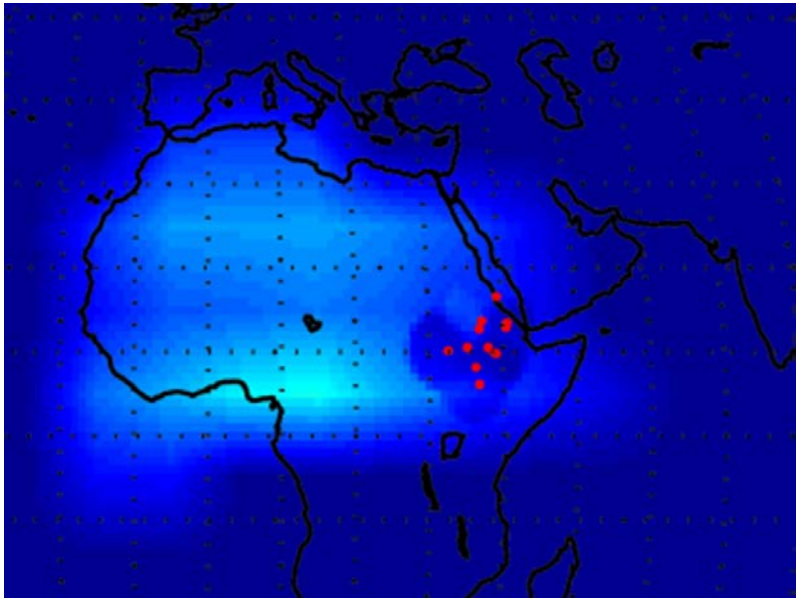




GISM model: Beniguel & Hamel, SWSC, 2011
Mapping technique: Jakowski et al., Radio Sci., 2011

Scintillation map on 8 April, 2015, 21:05 UT





GISM model: Beniguel & Hamel, SWSC, 2011
Mapping technique: Jakowski et al., Radio Sci., 2011

Summary & conclusion

- Seasonal statistics of S_4 with maxima around equinoxes confirms former studies, asymmetry between spring and autumn needs further investigation.
- GPS, GLONASS and Galileo systems show different sensitivity to ionospheric irregularities.
- Local network of scintillation receivers in Bahir Dar allows detecting plasma bubbles and their drift velocities.
- Availability of different GNSS makes scintillation mapping attractive.
- To explore the structure and dynamics of plasma bubbles, the current local GNSS network should be extended.
- Comparative measurements with complementary techniques should be performed.

Thank you for your attention!

Contact:

Dr. Norbert Jakowski
Kalkhorstweg 53
D-17235 Neustrelitz
Germany
Tel. +49 (0)3981 480 - 151
Fax. +49 (0)3981 480 - 123
Email: Norbert.Jakowski@dlr.de
Web: www.dlr.de/kn http://swaciweb.dlr.de